# The California Rockfish Conservation Area and Groundfish Trawlers at Moss Landing Harbor

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# Overview and motivation

- Rebuilding stocks of bocaccio, canary, darkblotched, widow, yelloweye rockfish ...
- Bycatch for groundfish trawlers that target dover sole, thorny heads, sablefish …
- Spatial regulations could protect overfished stocks and allow opportunities for others

# Economic Effects of Spatial Management

- A = Net Revenue Per Unit Effort in an Area
- H = Fishing Effort in an Area
- Fishery Economic Value in an Area V = A H
- Decomposition of Change in Value:

$$A' H' - A H = ( A' - A ) H' + A ( H' - H )$$

- Conclusion: Effort shifts *and* changes in RPUE important for evaluating spatial management

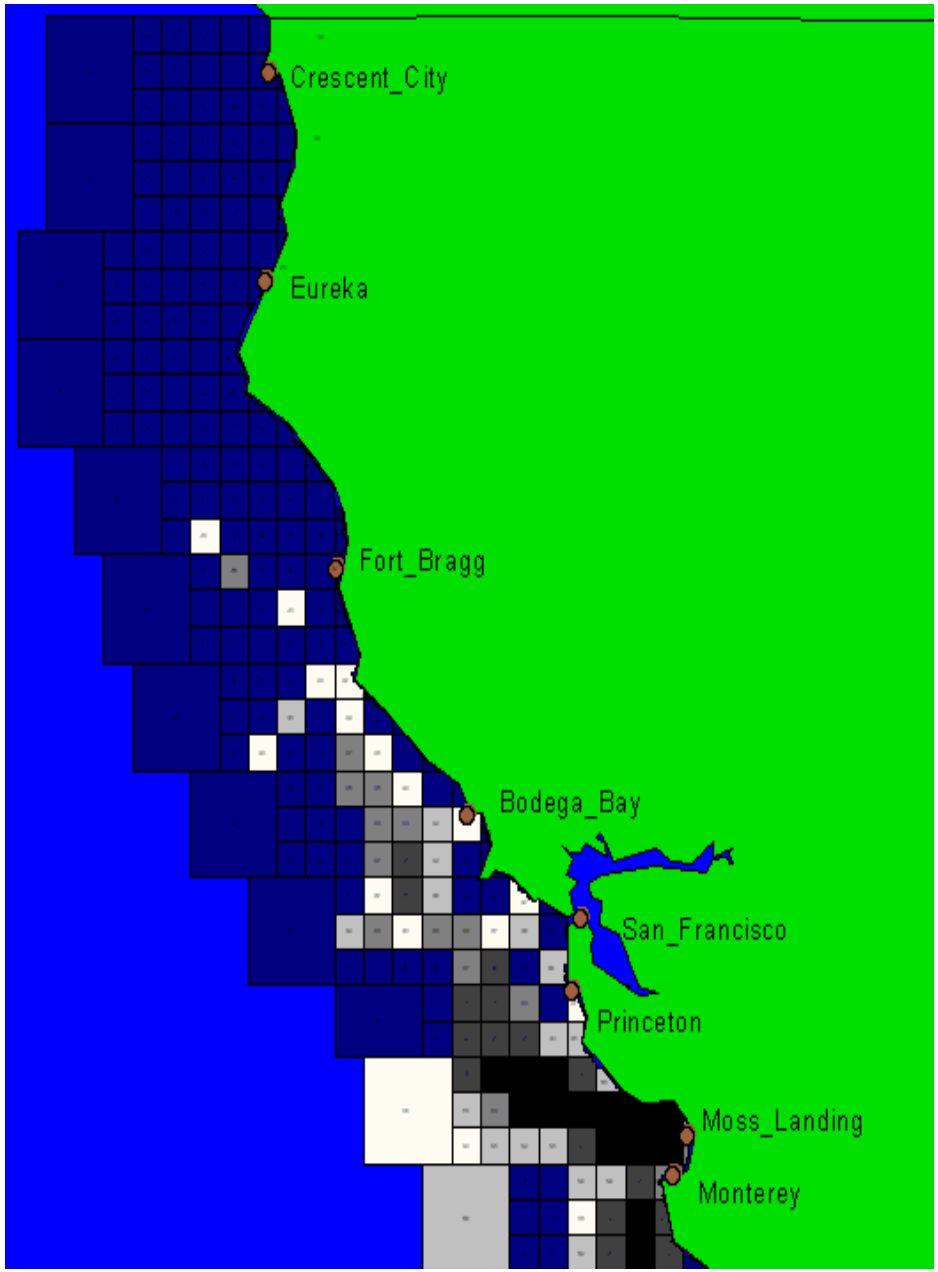
# Recent West Coast Spatial Management

- Marine Reserves Processes
  - Channel Islands National Marine Sanctuary
  - California Marine Life Protection Act
- Pacific Fishery Management Council
  - 2003 Groundfish Regulations
  - Bycatch and Discard Analysis

# Policy and Management Implications

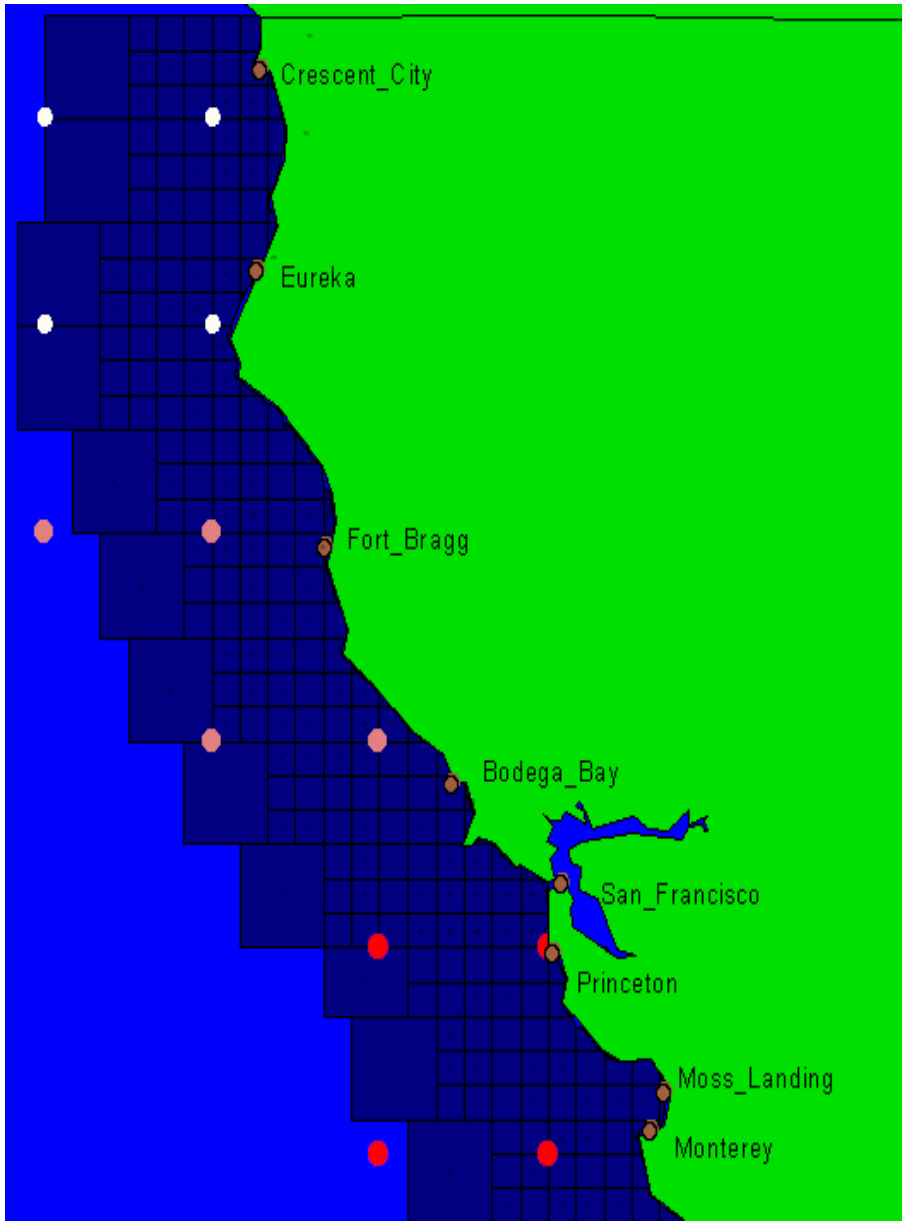
- Economic analysis for Channel Islands:
  - Cost = -A H in closed area, claim upper bound
  - Ignores effort shift, RPUE change in open area
- PFMC analysis of 2003 regulations
  - Estimates effort shift but not RPUE change
- Neither analysis has statistical basis
- Objective here to provide statistical basis for analyzing shifts in effort and changes in RPUE

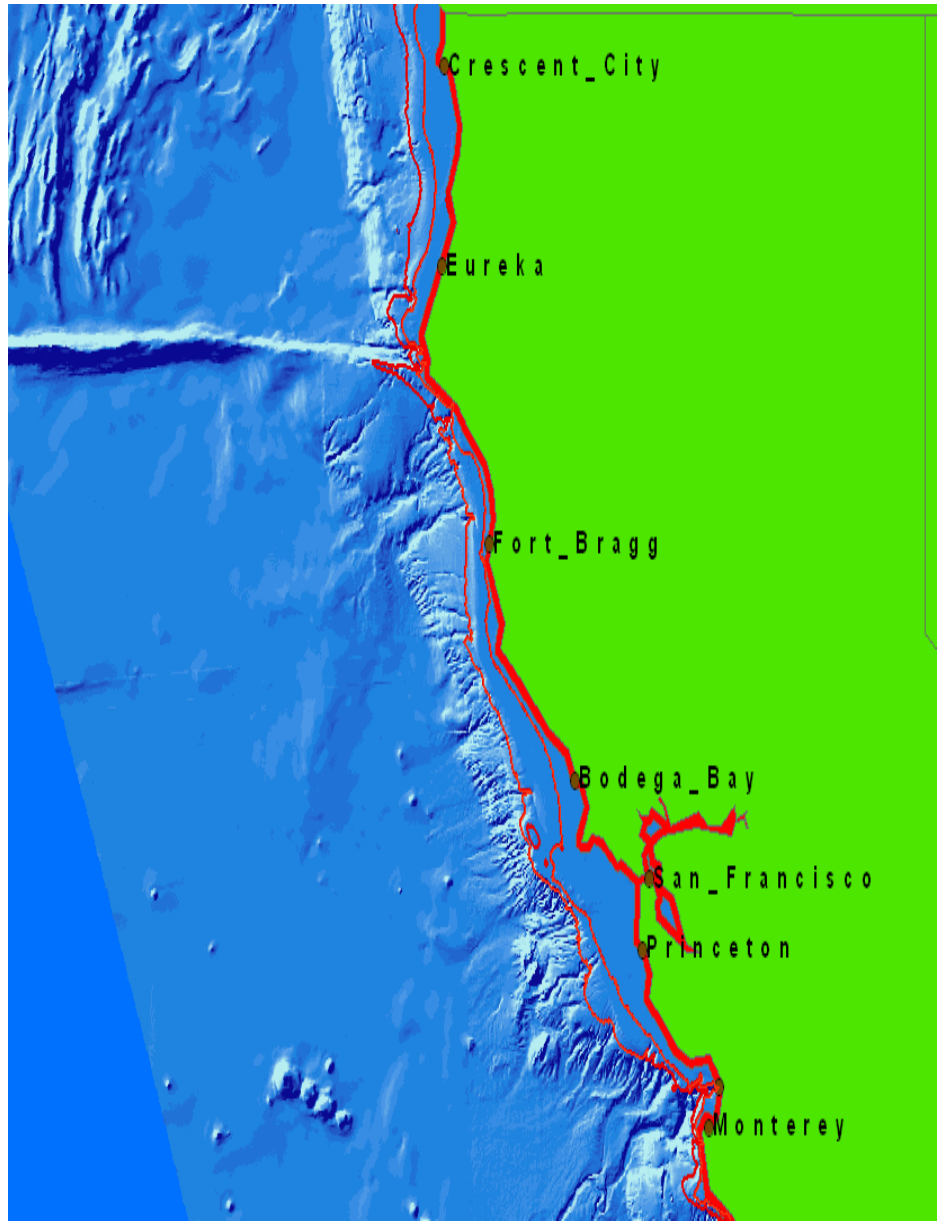
# PacFIN Data and GIS analysis



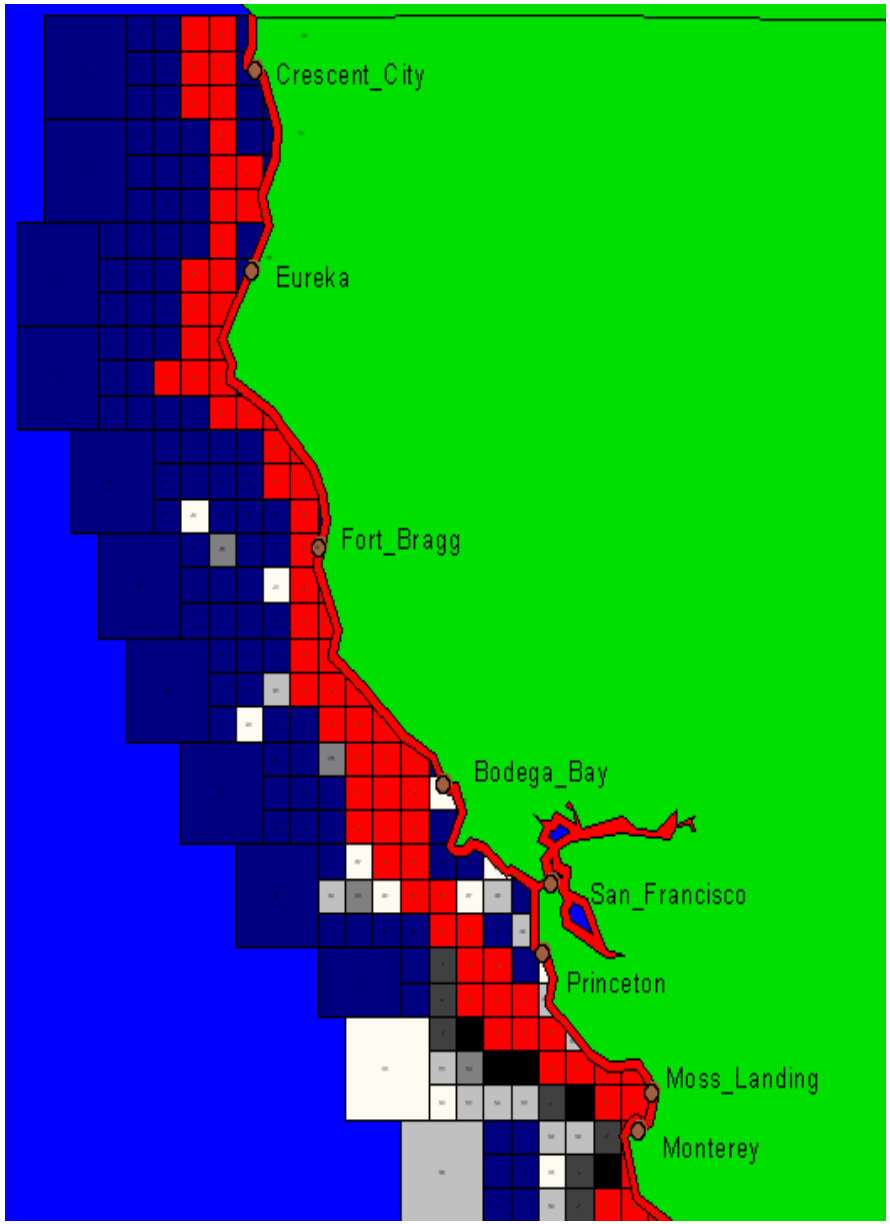

- California PacFIN trawler logbook and ticket data
- 1981-2001, north of Point Conception
- GIS by port and DFG fishing blocks
- Query GIS for Moss Landing data on tow hours, catch, and ex vessel prices

# IRI SST and DFG bathymetry data



# California Rockfish Conservation Area (CRCA)

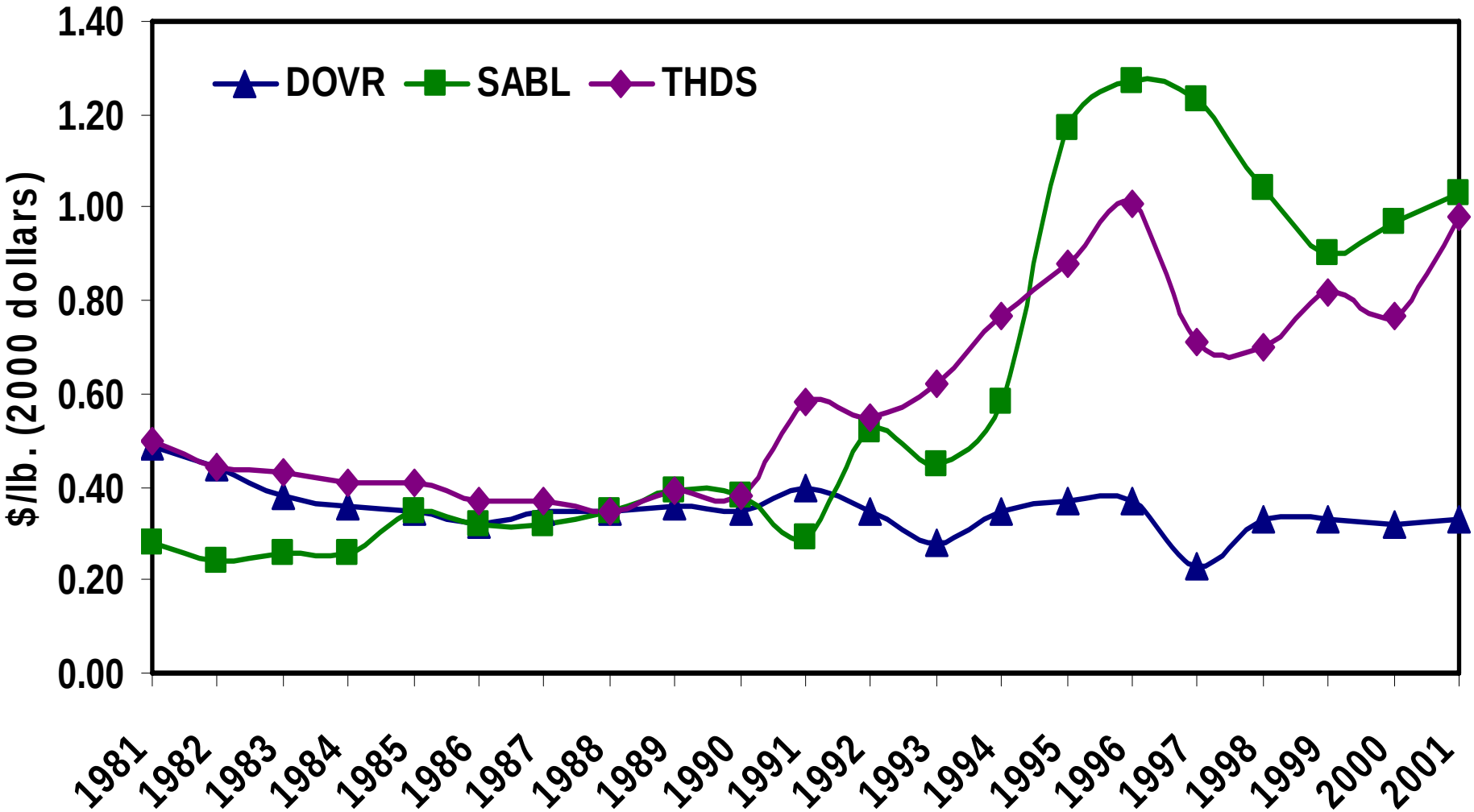



- CRCA
  - Inshore zone >3nm and <50-60fm
  - Offshore zone >150fm Pt. Reyes south, >250fm north
- Area 1: DFG blocks inside CRCA
- Area 2: DFG blocks outside CRCA

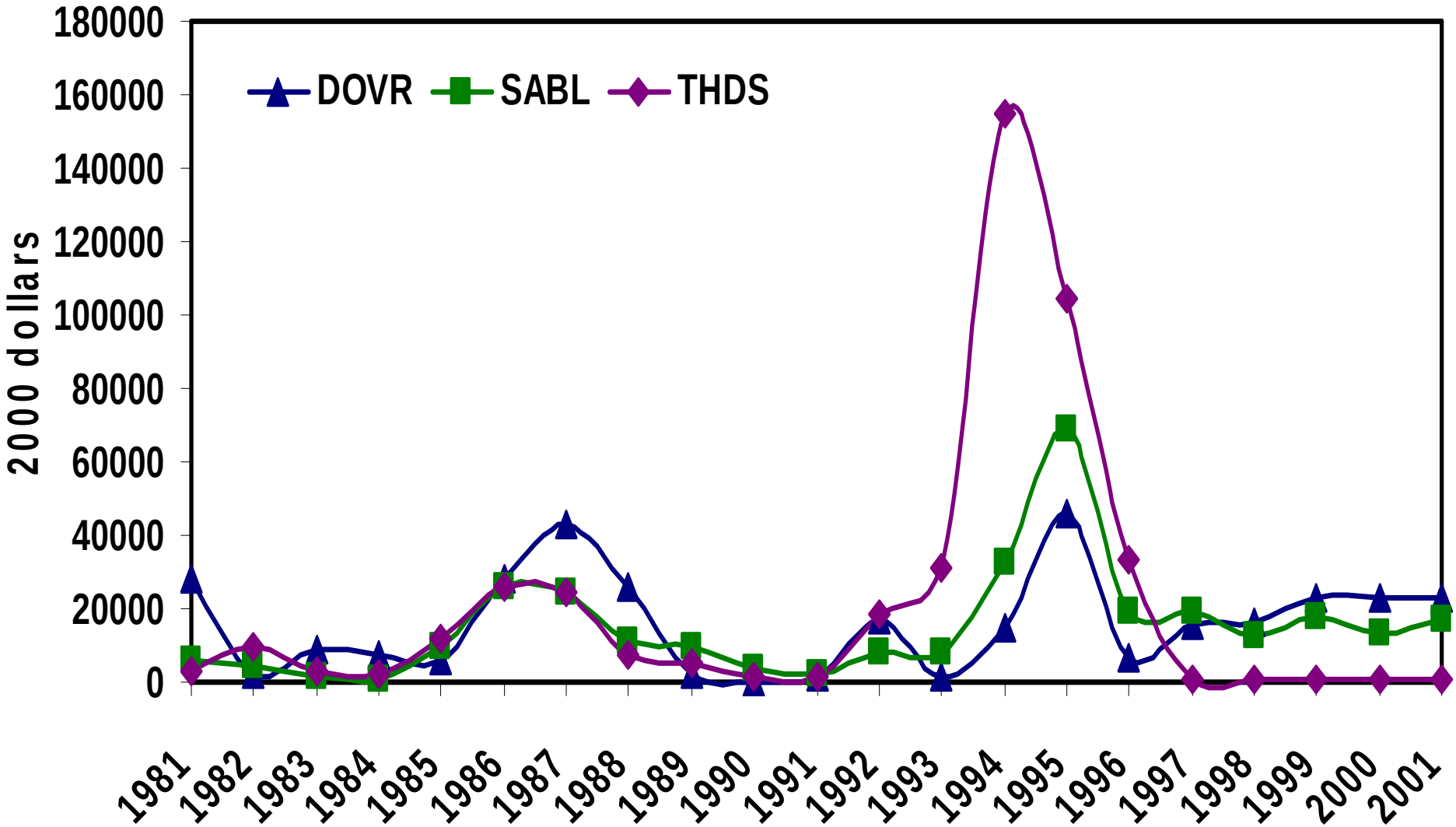
# Data for vector autoregression (VAR) analysis

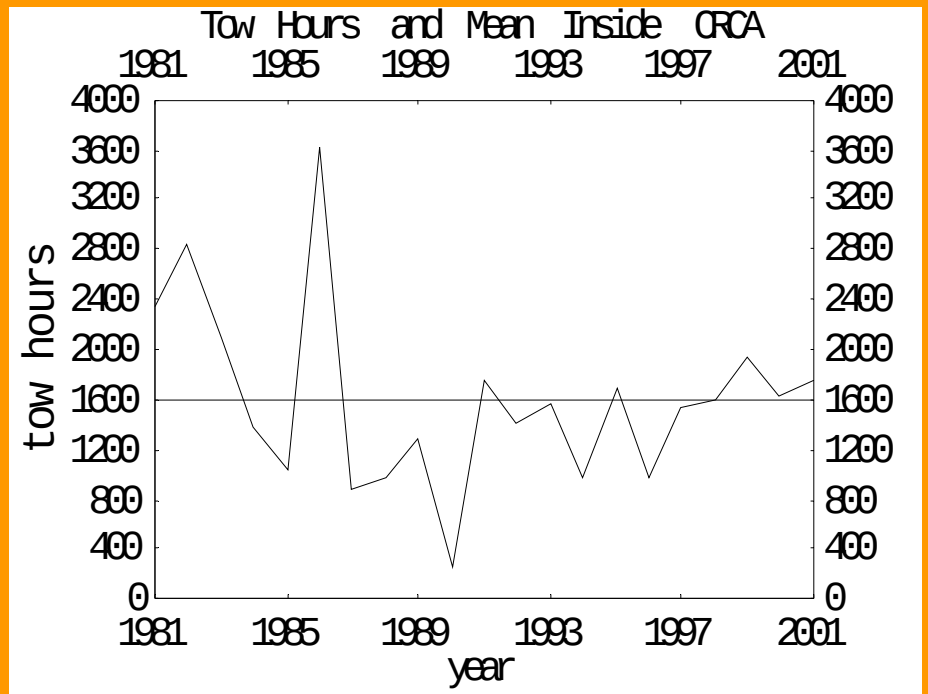
- Compile time series data for Moss Landing
  - Total tow hours for blocks inside and outside CRCA, 1981-2001
  - Cumulative ex vessel prices for DTS species at Moss Landing
  - Nov-March Average sea surface temperatures (SST) for ENSO index
- Quadrivariate (four variable) VAR
  - Data are deviations from means
  - Data are covariance stationary
  - Second-order restrictions appropriate

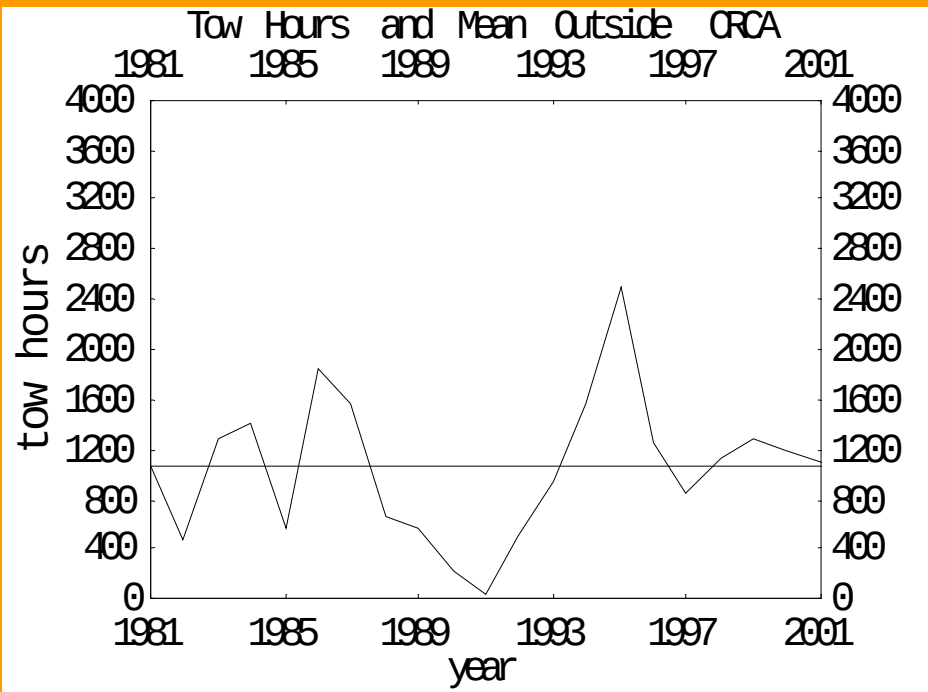
# DTS Ex Vessel Prices at Moss Landing



# DTS Revenues at Moss Landing




Tow Hours and Mean Inside CRCA
tow hours
year
1981
1985
1989
1993
1997
2001
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000


Tow Hours and Mean Outside CRCA
tow hours
year
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1985
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2001
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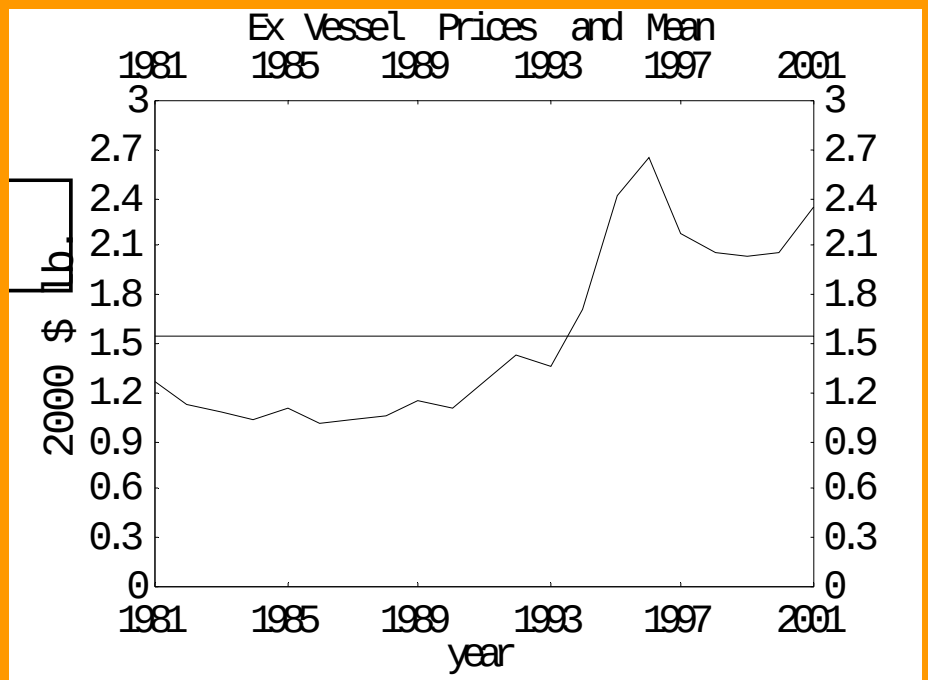
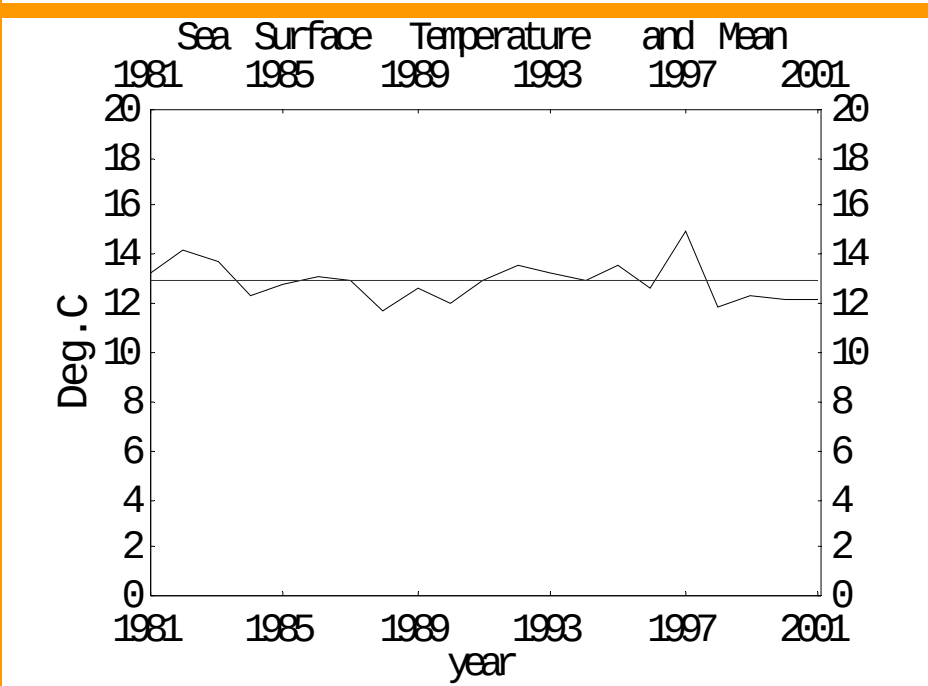

Ex Vessel Prices and Mean
2000 $ Lb.
year
1981
1985
1989
1993
1997
2001
0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
3


Sea Surface Temperature and Mean
Deg.C
year
1981
1985
1989
1993
1997
2001
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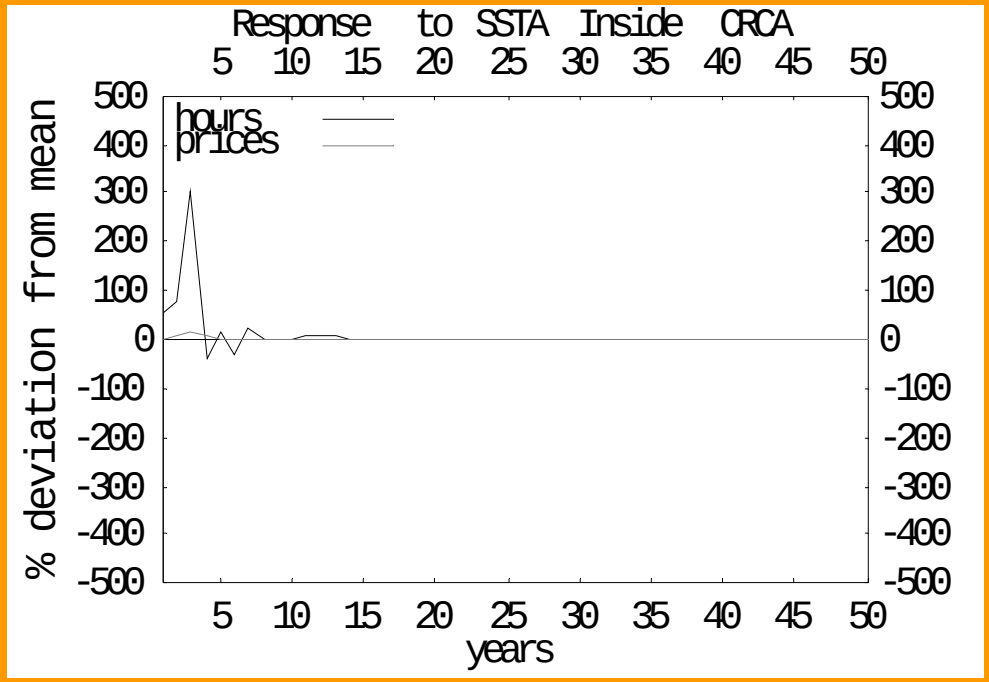
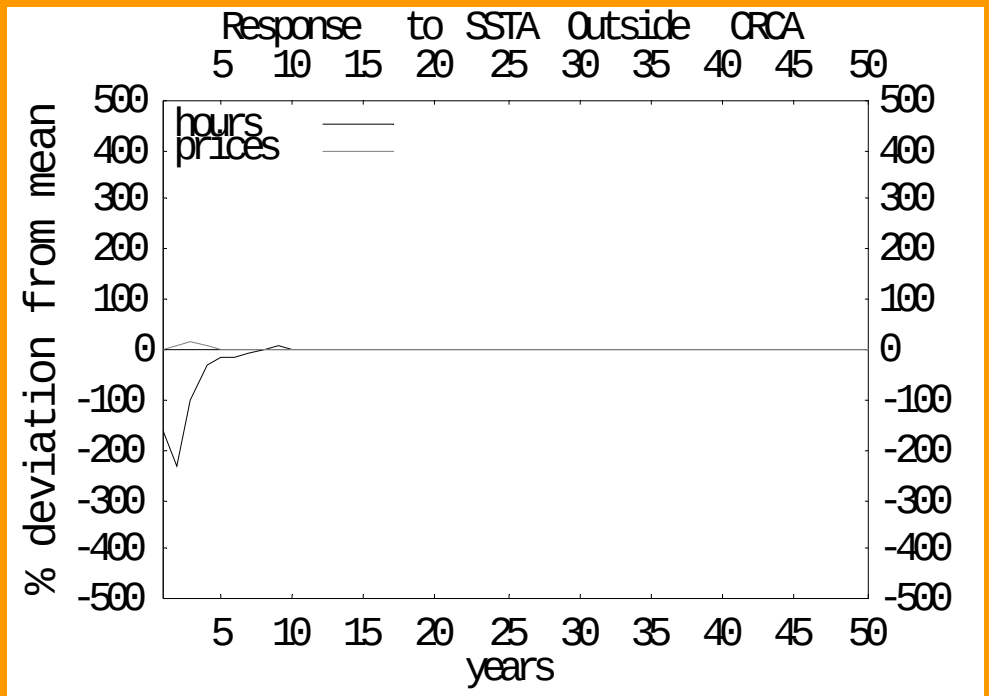
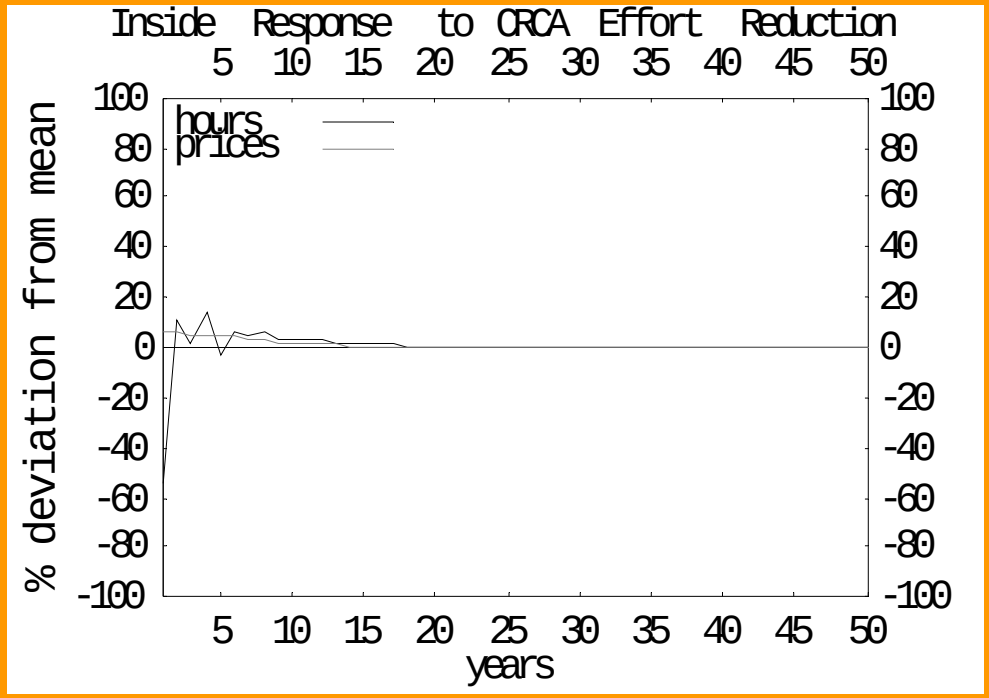
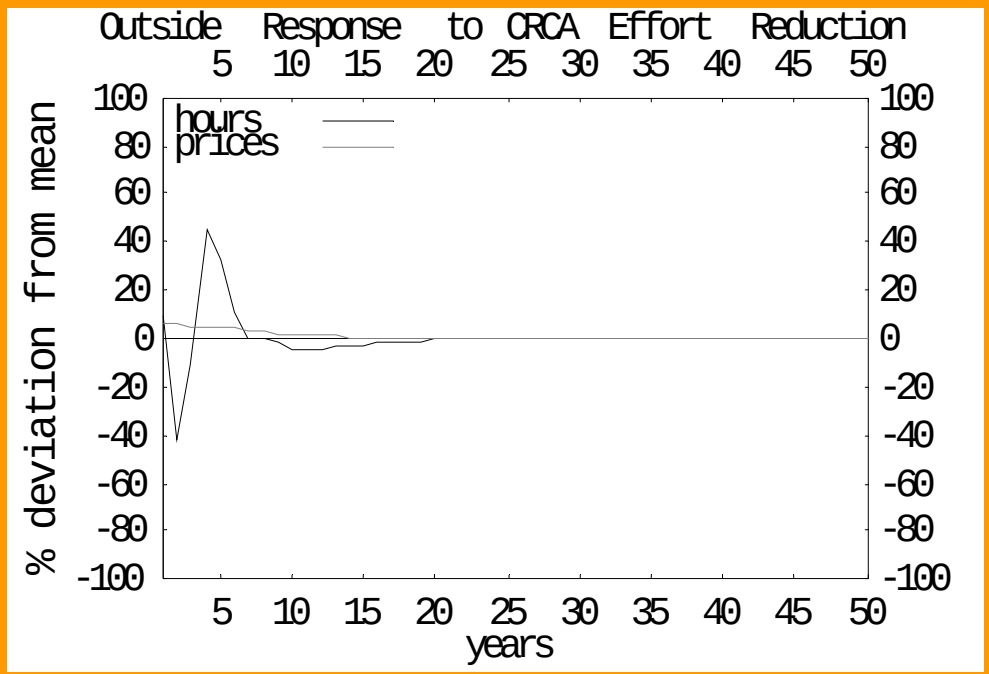
2
4
6
8
10
12
14
16
18
20




- **Orthogonalized impulse response functions simulate 1997-98 ENSO**
- **Increase in effort inside CRCA**
- **Decrease outside**
- **Inshore movement of effort from ENSO**
- **Modest increase in ex vessel prices**




- **Response to a temporary effort reduction in the CRCA equal to total tow hours in 2001**
- **Reduction inside CRCA followed by rapid return to mean**
- **Increase outside with oscillations**
- **Modest increase in ex vessel prices**

# Granger causality tests

- Multivariate test rejects excluding effort outside CRCA from the VAR at 5% significance level
- Effort outside CRCA could be Granger causing:
  1. Ex vessel prices
  2. Fishing effort inside CRCA
  3. SST (fishermen's expectations)
- Bioeconomic model here allows 3 only
- Bivariate tests inconclusive
- T-statistics from VAR support 3

# Bioeconomic Model components

- Two area model with stochastic dynamics
- Net RPUE $A_t$ depends on
  - Effort $H_t$ in the area (crowding externality)
  - Abundance $N_t$ in the area (dynamic externality)
  - Ex vessel prices $P_t$ at the port
- $A_t = f_0 + f_1 H_t + f_2 N_t + f_3 P_t$

# Bioeconomic Model components

- Abundance $N_t$ depends on
  - Effort $H_t$ in the area (fishing mortality)
  - Lagged abundance $N_{t-1}$
  - Stochastic recruitment or migration $X_t$
- $N_t = g_0 + g_1 H_t + g_2 N_{t-1} - g_1 g_2 H_{t-1} + X_t$
- Stochastic recruitment depends on
  - Sea surface temperature $S_t$
  - random factor $Y_t$
- $X_t = \tau S_t + Y_t$

# Bioeconomic model components

- SST and $Y_t$ are first order Markov processes
  - $S_t = \rho S_{t-1} + \varepsilon_{st}$
  - $Y_t = \lambda Y_{t-1} + \varepsilon_{yt}$
- Ex vessel prices have a first-order form
  - $P_t = \varphi_1 P_{t-1} + \varphi_2 S_{t-1} + \varepsilon_{pt}$
- The $\varepsilon_{kt}$ are least-squares residuals with finite variance and zero conditional mean

# Fisherman's problem

- Dynamic and spatial adjustment costs

$$R = \frac{1}{2}\begin{pmatrix} r_1 & 0 \\ 0 & r_2 \end{pmatrix}$$

- Each fisherman has discount factor $0 < \beta < 1$ and chooses random vectors of fishing effort $h_t$ to maximize an expected present value of profits:

$$E \Sigma_t \beta^t \left( A_t h_t - (h_t - h_{t-1})' R (h_t - h_{t-1}) \right)$$

# Model solution and regression equations

- Solution given by stochastic Euler equations and transversality conditions
- Solving the fisherman's problem involves many tedious steps of algebra
- Highlights are
  - Factoring characteristic matrix polynomial
  - Wiener-Kolmogorov prediction formula
  - Construction of orthogonal forecast errors
- End result: system of four regression equations that incorporate parameter restrictions of rational expectations hypothesis

# Maximum likelihood estimates

| Parameter | Equation/Variable | CRCA | Outside | Joint |
|---|---|---|---|---|
| $f_1$ | RPUE/Effort | -0.881 | -0.501 | |
| $f_2$ | RPUE/Stock | 0.194 | 0.166 | |
| $f_3$ | RPUE/Price | 0.094 | 0.009 | |
| $g_1$ | Stock/Effort | -0.013 | -0.233 | |
| $g_2$ | Stock/Stock | -0.028 | 0.031 | |
| r | Adjustment Cost | 0.007 | 0.489 | |
| $\tau$ | Stock/SST | 0.231 | -0.257 | |
| $\lambda$ | Random | -0.296 | 0.077 | |
| $\varphi_1$ | Price/Price | | | 0.963 |
| $\varphi_2$ | Price/SST | | | 0.048 |
| $\rho$ | SST | | | -0.126 |

# Likelihood ratio tests of bioeconomic model

| Test | Statistic | Significance |
|---|---|---|
| **Asymptotic $\chi^2$** | **12.354** | **0.09** |
| **Small Sample** | **5.491** | **0.60** |

- Bioeconomic model tested against less restricted third-order VAR alternative
- First test statistic has asymptotic chi-squared distribution
- Second test statistic modified for small sample bias
- Neither test rejects bioeconomic model at 5% significance level

# Conclusions

- VAR analysis shows significant differences inside and outside CRCA
  - Inshore movement from ENSO
  - Effort displacement from CRCA
- Bioeconomic model gives reasonable results
  - RPUE inside CRCA more sensitive to vessel crowding
  - RPUE inside CRCA more sensitive to changes in ex vessel prices
  - Adjustment costs greater outside CRCA
  - Stock/SST effects support VAR results

## Next steps for data and model development

- Historical regulatory data including trip limits for DTS species from SAFE documents
- Species detail from stock assessments, rebuilding analyses, etc. to identify additional parameters and estimate bycatch
- Relax model assumptions to predict effort shifts

1. Adjustment costs
2. Stock recruitment and migration
3. Address effort and ex vessel prices

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